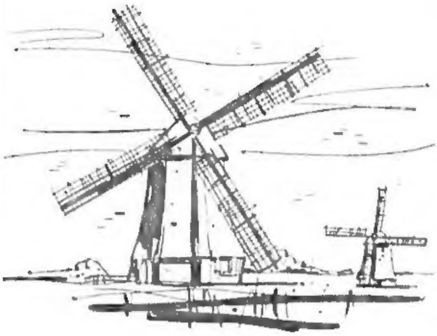
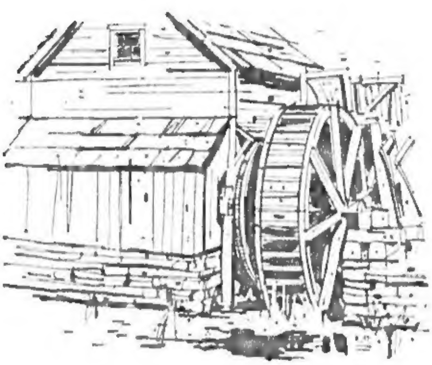
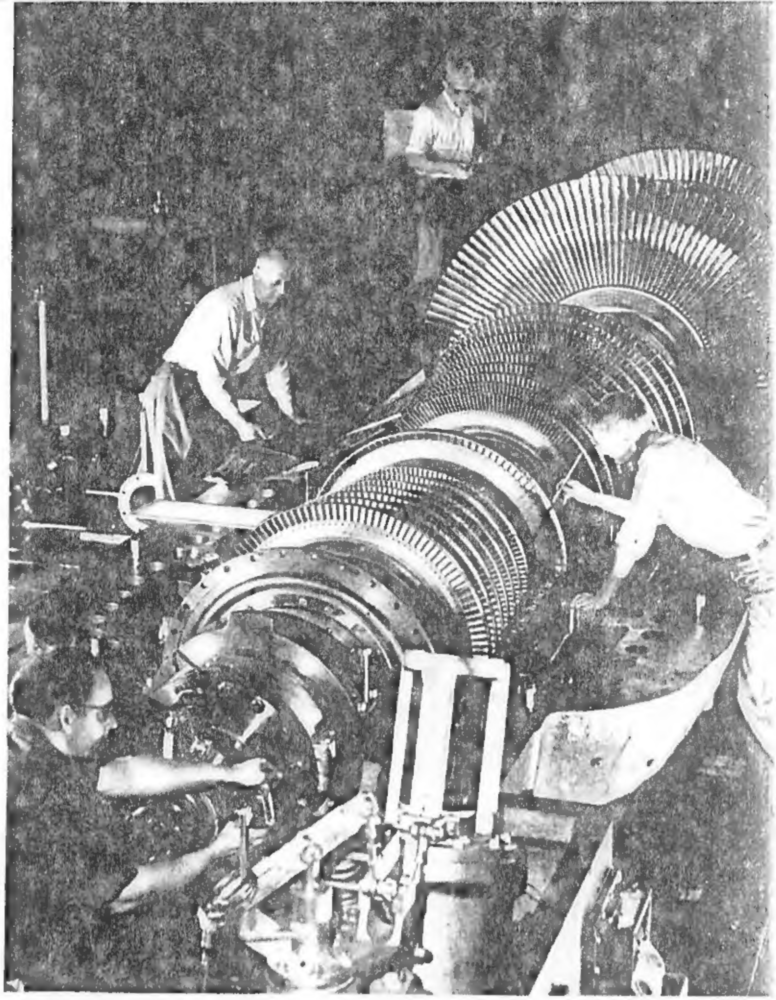
# TURBINE







General Electric Co.

**A Powerful Steam Turbine** can generate all the electricity needed by about 1,000,000 people. Rushing steam spins bladed wheels, such as those in this partly-assembled turbine. Turbines were developed from the simple windmill, *upper left*, and water wheel, *lower left*.

**TURBINE,** *TUR bihn* or *TUR byn,* is a wheel turned by the force of a moving fluid, such as water, steam, or gas. It changes the force of the fluid into energy that can be used for work. Turbines rank among the simplest and most powerful machines. Generators driven by turbines produce electricity to light homes and to run factories. Turbines also drive ocean liners and some airplanes. A water wheel and a windmill are both turbines. So is a pinwheel that spins when you blow on it. The word *turbine* comes from the Latin word *turbo,* meaning that which *spins* or *whirls around.*

A turbine does not create power. It changes the force of moving fluids into *rotary,* or circular, motion. This motion can do useful work. For example, flowing water spins a water wheel below a dam. The water wheel turns a generator that produces electricity, which lights homes and drives machinery. In this way, the energy of the flowing water is put to work. Nuclear power plants also use turbines to produce electricity.

There are three main kinds of turbines: (1) water, (2) steam, and (3) gas. Wind turbines are a fourth kind. But they can be used only in a few regions that have fairly steady winds. Water, steam, and gas turbines generate most of the electric power used today.

### How Turbines Work

A paper pinwheel, the simplest kind of turbine, turns when you blow on it. But it does not produce much

### TURBINE TERMS

**Buckets** are the parts of the turbine wheel that the moving fluids push against. They may be shaped like *scoops,* or like *blades* or *vanes* similar to the slats of a Venetian blind or the blades of a propeller.

**Casing** is the outside shell of a turbine. It holds the flowing fluids against the turbine wheel.

**Condenser** is a cooling device that changes the exhaust steam from a steam turbine into water.

**Exhaust** is the part of a turbine where the used fluids come out. The channel for the exhaust water from water turbines is called a *tailrace.*

**Nozzles** are the parts of the casing that aim moving fluids against rows of buckets. They may look like curved blades or like nozzles of garden hoses.

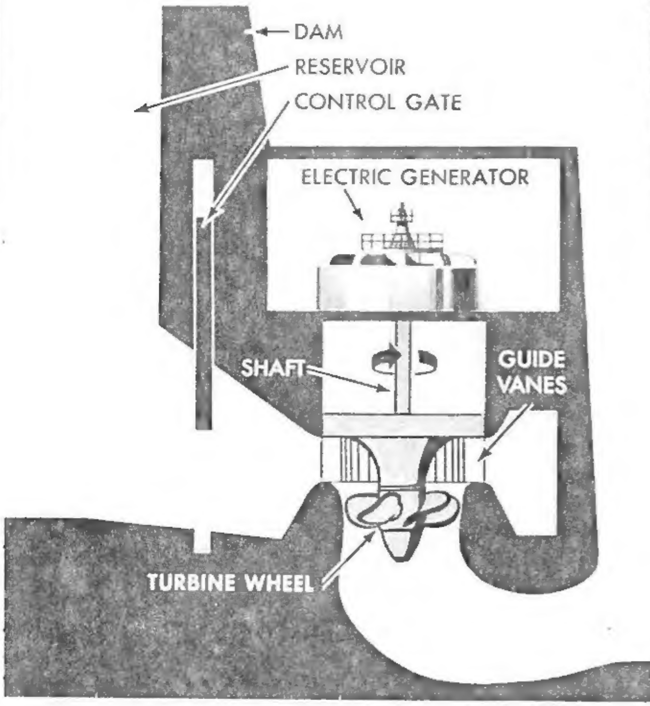
**Rotor** is the rotating part of a turbine. It includes the buckets and the shaft on which they are mounted.

**Stage** is a single wheel of rotor buckets and its fixed ring of nozzles. Most steam and gas turbines have many stages, or sets of bucket wheels and nozzles. A water turbine usually has only one stage.

**Throttle** is a valve or faucet that controls the flow of fluids into a turbine.

# WATER TURBINES

**Reaction Water Turbines** usually turn generators at dams. The weight, or pressure, of the flowing water turns the turbine wheel. A control gate in the dam, and guide vanes, regulate the water flow.




Allis-Chalmers Corp.

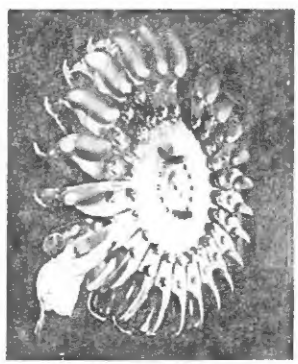
**Kaplan-Type Wheels,** used in reaction water turbines, look like huge propellers. This wheel, installed at a TVA dam in Kentucky, dwarfs the man standing on top of it.

2,000 pounds per square inch (140 kilograms per square centimeter).

Steam rushes into the turbine at 1,000 miles (1,600 kilometers) per hour. It strikes the first wheel, giving it a push, goes on to the next wheel, and then the next. A modern steam turbine has as many as 24 wheels mounted on a horizontal shaft. In front of each wheel is a fixed ring of curved, blade-shaped nozzles fastened to the casing. The nozzles direct the steam to meet the wheels at the proper angle. The steam follows a zigzag path between the nozzles and the turbine wheels.

Steam expands as much as 1,000 times its original volume as it passes through the turbine. Therefore, each succeeding pair of nozzles and wheels must be larger than the last one to make use of all the expanding steam. This gives the steam turbine its typical trumpet-like shape. To obtain just the right effect from the rushing steam, engineers carefully design the blades of each wheel and ring of nozzles. A steam turbine must be built of especially strong steel. It usually runs red-hot 24 hours a day, 7 days a week, for months or even years without stopping.

Steam turbines have impulse-type and reaction-type wheels, just as water turbines do. In an impulse turbine, the shape of the nozzles allows the steam to expand before it hits the blades of the wheels. In a reaction turbine, the steam expands while passing through the blades of the wheel. The expansion and speed of the steam helps push the wheel. Most modern turbines use both types of wheels at different stages along the shaft.



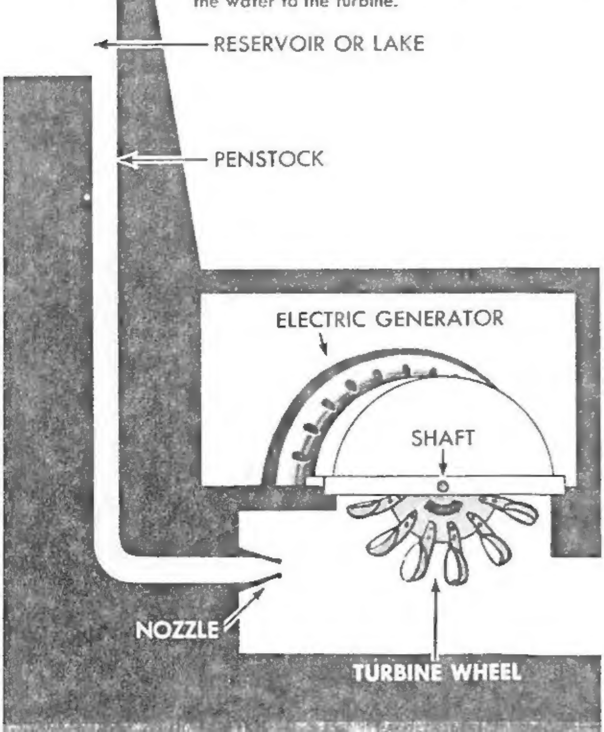
Allis-Chalmers Corp.

**Cup-Shaped Buckets** rim the edge of a Pelton wheel. Nozzles squirt water at the buckets.

After the spent and expanded steam leaves the last wheel, it goes to the *condenser*. This is a large chamber with a network of pipes through which cooling water flows. The condenser cools the steam into water, which falls to the bottom of the condenser. A pump sends the water back to the boiler to be made into steam again. The condenser creates a vacuum, because the water takes up only about $\frac{1}{30,000}$ of the space of low-pressure steam. The vacuum helps pull more steam through the turbine.

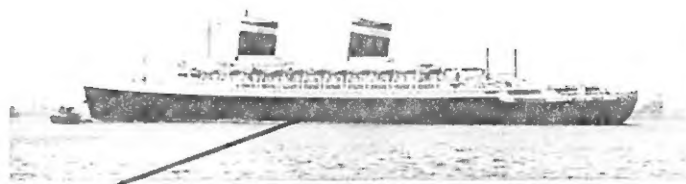
In $\frac{1}{30}$ of a second, the steam travels through the turbine to the condenser. It drops in temperature from 1050° F. (566° C) to less than 100° F. (38° C). The pressure drops from 2,000 pounds to about ½ pound per square inch (140 kilograms to 0.04 kilogram per square centimeter). This is about 4 pounds (0.3 kilogram) less than the air pressure on top of Mount Everest.

**Impulse Water Turbines** such as the *Pelton wheel* work best where water falls a long distance, as from a mountain lake to a valley. The force of the water striking the wheel makes it spin. Long pipes that are called *penstocks* carry the water to the turbine.

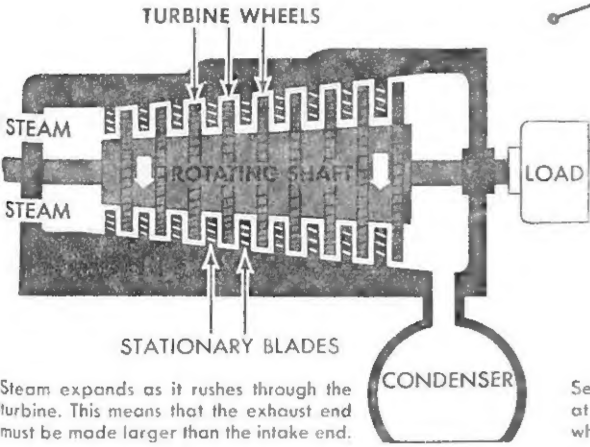


# STEAM TURBINE

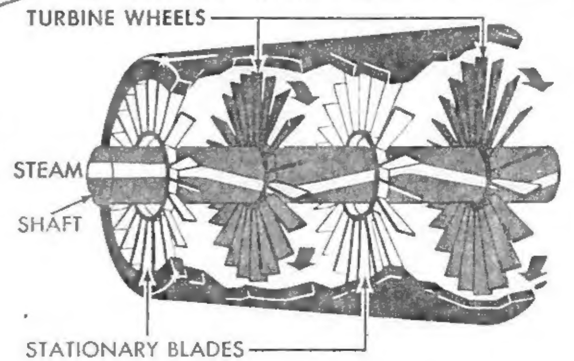
Whirling steam turbines spin the propellers of huge ocean liners, turn electric generators, and run pumps. Steam from a boiler rushes through the turbine, rotating a series of bladed wheels mounted on a long shaft. As the steam leaves the turbine, a condenser cools it and changes it into water. This creates a vacuum that sucks steam through the turbine.



S.S. United States, Port Authority of New York and New Jersey




Steam expands as it rushes through the turbine. This means that the exhaust end must be made larger than the intake end.




Sets of stationary blades fastened to the turbine casing aim the steam at the wheels. These blades guide the steam so that it strikes the wheels at the correct angle. Each wheel has its own set of aiming blades.

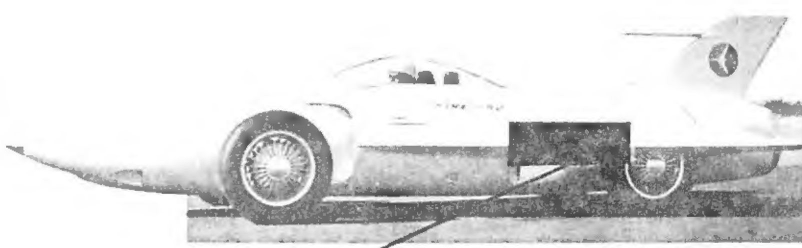
Steam-turbine plants usually stand near railroads or other transportation facilities, so that fuel for their boilers can be delivered easily. Some steam-turbine plants burn huge amounts of coal daily. These plants must also be near a good water supply, to obtain cooling water for their condensers. One power station in New York City pumps 3,600,000 short tons (3,270,000 metric tons) of water a day through its condensers. This is more water than all the rest of the city uses daily. In a modern steam turbine plant, for every short ton of coal that is burned, 12 tons of air must be blown into the furnace, 13 tons of combustion gases go up the furnace chimney, and about 10 tons of water must be supplied to the boiler. However, the same water can be pumped back to the boiler from the condenser and used again and again.

**Gas Turbines** work much like steam turbines, but use hot gases instead of steam. Any burning fuel produces hot gases such as those you see in the flame of fire. Gas turbines use these hot gases directly, without first using them to heat water into steam. They burn fuels such as oil, kerosene, and natural gas. Engineers hope to use synthetic gases made from coal as a fuel in gas turbines some day.

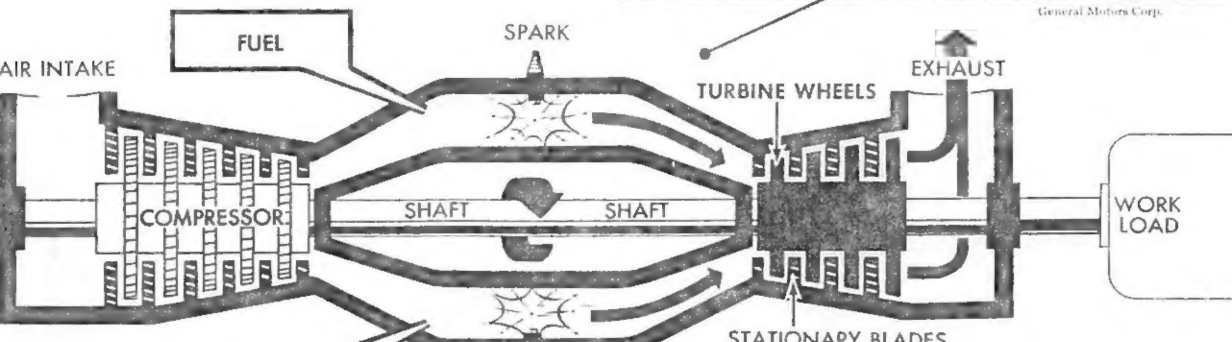
Gas turbines have three main parts: (1) a compressor, (2) a combustion chamber, and (3) one or more turbine wheels. The *compressor* is a special-type fan that sucks in air and compresses it. The compressed air mixes with

# GAS TURBINE

Gas turbines turn electric generators and drive ships and airplanes. They also have been tried experimentally in automobiles. In a gas turbine, a compressor forces air into a combustion chamber where it mixes with fuel. An electric spark ignites the fuel-air mixture, creating hot gases that blast through the turbine.



General Motors Corp.




Fixed sets of blades aim the hot gases at the turbine wheels. The turbine spins the compressor, besides turning a generator, running a pump, or doing other work.

the fuel and burns in the *combustion chamber*. The burning gases expand enormously and rush through the turbine, spinning the *turbine wheels*. Part of the rotary power from the turbine wheels drives the air compressor. This compressor is often mounted on the same shaft as the wheels. The rest of the rotary power can turn electric generators, run pumps, or drive ships.

Gas turbines are designed to make use of their hot exhaust gases. For example, a gas turbine used to turn an electric generator has a waste-heat recovery device called a *regenerator*. The regenerator uses heat from the exhaust gases to warm up the high-pressure air from the compressor before it enters the combustion chamber. By preheating the air, the regenerator reduces the amount of fuel needed for the combustion process. Other types of gas turbines, including turbojet and turbofan engines for aircraft, use the energy from exhaust gases for power. The gases are forced out the tailpiece of such turbines at high speed to produce forward thrust. See JET PROPULSION.

Gas turbines run at even hotter temperatures than steam turbines do. Engineers must make gas turbines from metals that keep their strength and shape in heat that would weaken steel. The temperature in many gas turbines is 2,000° F. (1093° C) or higher. The hotter a gas turbine runs, the more efficiently it operates. But a gas turbine works best only when run at from three-fourths of full power to full power. This can be a disadvantage when the turbine is used to propel ships, which often must move slowly. Gas turbines are usually very light and small for the power that they produce. For example, gas turbines that are used on land and in ships produce 3,000 to 30,000 horsepower (2,200 to 22,000 kilowatts), and they have an average weight of from 5 to 15 pounds per horsepower (3 to 9 kilograms per kilowatt).

### History

**Early Days.** Water wheels are so old that no one knows who invented them. The ancient Greeks, Egyptians, and other peoples in the Mediterranean area used water wheels to grind grain and to irrigate crops.

Hero of Alexandria described the first known steam turbine about A.D. 60. It consisted of a small metal globe mounted on a pipe leading from a steam kettle. Steam from the kettle escaped from two pipes fastened to opposite sides of the globe and whirled it around. See JET PROPULSION (picture: The First Jet Engine).

Windmills first came into use in the Middle East in the 900's and in Europe in the 1100's. In the 1600's, people built the first crude gas turbines by mounting fans over a cooking fire to turn roasting meat on a spit. The hot gases from the fire spun the fan. Gears connected the fan to the spit.

These first forms of the turbine worked inefficiently, because much of the flowing fluids escaped around the sides of the turbine wheels. Benoît Fourneyron (1802-1867), a French engineer, developed the first fully successful enclosed water turbine in 1832. It developed 50 horsepower (37 kilowatts) and drove hammers used to forge metal. After Fourneyron's success, engineers soon overcame most of the problems that were involved in building efficient water turbines. By 1855, a Paris waterworks had a turbine that provided 800 horsepower (600 kilowatts).

Carl Gustaf de Laval (1845-1913), a Swedish engineer, built an impulse steam turbine in 1883 to power a cream separator he had invented. One year later, Charles A. Parsons (1854-1931) developed a reaction steam turbine in England. About 1900, Charles G. Curtis (1860-1953), an American inventor, developed the first steam turbine using many sets of wheels. The first big Curtis turbine was installed at an electric-power plant in Chicago in 1903. It ran a generator that produced 5,000 kilowatts of electricity. This Curtis turbine started a revolution in power production. It took up one-tenth as much space as the steam piston engine it replaced, weighed one-eighth as much, cost one-third as much, and used less steam. French and Swiss engineers also did important pioneering work on steam turbines.

**Recent Developments** include the perfection of the gas turbine during World War II. Gas turbines could not be built until engineers learned how to make metals that could withstand the great heat inside the combustion chamber. Gas turbines are now used in electric-power plants, pipeline pumping stations, and heavy industry. They power ships and experimental cars and trucks. In 1963, the Chrysler Corporation tested 50 gas-turbine powered cars.

Engineers have designed and built steam turbines capable of using steam at pressures of more than 4,500 to 5,000 pounds per square inch (316 to 350 kilograms per square centimeter). Such high-pressure steam enables turbines to produce more power with less fuel. In 1957, the American Gas and Electric Company installed a turbine at its Philo, Ohio, plant that uses steam at a pressure of 4,500 pounds per square inch (316 kilograms per square centimeter) and a temperature of 1150° F. (621° C). This power station can produce a kilowatt-hour of electricity from only about $\frac{3}{4}$ pound (0.3 kilogram) of coal. The average power plant burns about 1 pound (0.5 kilogram) of fuel to produce one kilowatt-hour of electricity. Engineers also have designed more powerful steam turbines by combining two or more rotors, so that several turbines become in effect one machine.

GLENN B. WARREN

Critically reviewed by J. T. RETTALIATA

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**Outline**

**I. How Turbines Work**
- A. Water Turbines
- B. Steam Turbines
- C. Gas Turbines

**II. History**

**Questions**

Do turbines create power? Explain your answer.
In what ways can a pinwheel turbine be improved?
What are the two main kinds of water turbines?
What is the purpose of a condenser in a steam turbine?
Why were gas turbines not perfected until as recently as World War II?
What are the parts of a turbine rotor?
What are four basic kinds of turbines?
What serious disadvantage does a gas turbine have when it is used to drive a ship or locomotive?
What are the major uses of turbines?
Who invented the first steam turbine? How did it work?